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(54) **Circuit breaker with arc light absorber.**

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Description

The present invention relates to a circuit breaker according to the preamble of claim 1, as known for instance from FR—A—2 475 290. Such a circuit breaker, usable also as a current limiter or electromagnetic switch is provided with a small-sized container in which the generation of an arc takes place when separating the contacts.

Further from EP—A—0 098 308 and EP—A—0 092 189 circuit breakers are known, being provided with arc light absorbers. These patent applications lie within the terms of Art 54(3), EPC.

For better understanding of the invention a prior-art circuit breaker shall be described with reference to Fig. 1A—1C showing the known circuit breaker in different operating states.

Numeral 1 designates a cover, and numeral 2 a base, which constructs an insulating container 3 with the cover 2. Numeral 4 designates a stationary contactor, which has a stationary conductor 5 and a stationary contact 6 at one end of the conductor 5, and the other end of the conductor 5 becomes a terminal connected to an external conductor (not shown). Numeral 7 designates a movable contactor, which has a movable conductor 8 and a movable contact 9 disposed oppositely to the contact 6 at one end of the conductor 8. Numeral 10 designates a movable contactor unit, and numeral 11 a movable element arm, which is attached to a crossbar 12 so that each pole is constructed to simultaneously open or close. Numeral 13 designates an arc extinguishing chamber in which an arc extinguishing plate 14 is retained by a side plate 15. Numeral 16 designates a toggle linkage, which has an upper link 17 and a lower link 18. The link 17 is connected at one end thereof to a cradle 19 through a shaft 20 and at the other end thereof to one end of the link 18 through a shaft 21. The other end of the link 18 is connected to the arm 11 of the contactor unit 10. Numeral 22 designates a tiltable operation handle, and numeral 23 an operation spring, which is provided between the shaft 21 of the linkage 16 and the handle 22. Numerals 24 and 25 respectively designate a thermal tripping mechanism and an electromagnetic tripping mechanism, which are respectively defined to rotate a trip bar 28 counterclockwise via a bimetal 26 and a movable core 27. Numeral 29 designates a latch, which is engaged at one end thereof with the bar 28 and at the other end thereof with the cradle 19.

When the handle 22 is tilted down to the closing position in the state that the cradle 19 is engaged with the latch 29, the linkage 16 extends, so that the shaft 21 is engaged with the cradle 19, with the result that the contact 9 is brought into contact with the contact 6. This state is shown in Figure 1A. When the handle 22 is then tilted down to the open position, the linkage 16 is bent to isolate the contact 9 from the contact 6, and the arm 11 is engaged with a cradle shaft 30. This state is shown in Fig. 1B. When an overcurrent flows in the circuit in the closed state shown in Figure 1A, the mechanism 24 or 25 operates, the engagement of the cradle 19 with the latch 29 is disengaged, the cradle 19 rotates clockwise around the shaft 30 as a center, and is secured to a stopper shaft 31. Since the connecting point of the cradle 19 and the link 17 exceeds the operating line of the spring 23, the linkage 16 is bent by the elastic force of the spring 23, each pole automatically cooperatively breaks the circuit via the bar 12. This state is shown in Figure 1C.

Then, the bevavior of an arc which is generated when the circuit breaker breaks the current will be described below.

When the contact 9 is now contacted with the contact 6, the electric power is supplied sequentially from a power supply side through the conductor 5, the contacts 6 and 9 and the conductor 8 to a load side. When a large current such as a shortcircuiting current flows in this circuit in this state, the contact 9 is isolated from the contact 6 as described before. In this case, an arc 32 is generated between the contacts 6 and 9, and an arc voltage is produced between the contacts 6 and 9. Since this arc voltage rises as the isolating distance from the contact 6 to the contact 9 increases and the arc 32 is tripped by the magnetic force toward the plate 14 to be extended, the arc voltage is further raised. In this manner, an arc current approaches to the current zero point, thereby extinguishing the arc to complete the breakage of the arc. The huge injected arc energy eventually becomes in the form of thermal energy, and is thus dissipated completely out of the container, but transiently rises the gas temperature in the limited container and accordingly causes an abrupt increase in the gas pressure. This causes a deterioration in the insulation in the circuit breaker and an increase in the quantity of discharging spark out of the breaker, and it is thereby apprehended that an accident of a power source shortcircuit or a damage of a circuit breaker body occurs.

Summary of the invention

The present invention has improved the disadvantages of the above-described prior-art circuit breaker. More particularly, the present invention provides a novel circuit breaker with an arc light absorber based on the fact which has been solved by present inventors for an arc phenomenon, and in which a pair of side walls formed of an arc light absorber is provided with respect to an arc extinguishing plate.

Brief description of the drawings

Figure 1A is a fragmentary sectional front view showing the contact closed state of a prior-art, circuit breaker;

Figure 1B is a fragmentary sectional front view showing the contact open state by the operation of an operation handle of the circuit breaker in Figure 1A;

Figure 1C is a fragmentary sectional front view showing the contact open state at the overcurrent

operating time of the circuit breaker in Figure 1A;

Figure 2 is a view for explaining the flow of an arc energy produced at the contactor opening time;

Figure 3 is a view for explaining the state when the arc produced at the contactor opening time is enclosed in a container;

Figure 4 is a perspective view showing an inorganic porous material necessary to form an arc light absorber;

Figure 5 is a fragmentary sectional view of the part of the material expanded in Figure 4;

Figure 6 is a characteristic curve diagram for showing the relationship between the apparent porosity of the inorganic porous material and the pressure in the container for containing the material;

Figure 7A is a perspective view for explaining the essential portion of a circuit breaker according to one embodiment of the present invention;

Figure 7B is a side view of Figure 7A;

Figure 7C is a fragmentary sectional front view of the circuit breaker in Figure 7A;

Figure 8A and 8B are plan views of the vicinity of an arc extinguishing plate for explaining the behavior of an arc;

Figure 9A and 9B are plan and front views of the vicinity of the arc extinguishing plate for similarly explaining the behavior of the arc;

Figure 10A is a plan view for explaining the essential portion of the circuit breaker according to another embodiment of the present invention;

Figure 10B is a fragmentary sectional front view of Figure 10A;

Figure 11A is a plan view showing the arc extinguishing plate and the side walls of the circuit breaker according to another embodiment of the present invention;

Figure 11B is a side view of Figure 11A;

Figure 11C is a fragmentary sectional front view of the vicinity of the contact section of the above embodiment;

Figure 11D is a perspective view of Figure 11A;

Figures A of Figures 12A to 14A show plan views of the vicinity of the arc extinguishing plate of the circuit breaker according to still another embodiment of the present invention;

Figures B of Figures 12B to 14B show fragmentary sectional front views of B—B line in respective Figure A of the respective embodiments;

Figure 15 is a plan view of the arc extinguishing plate showing still another embodiment of Figure 14A;

Figure 16A is a plan view of the vicinity of the arc extinguishing plate of the circuit breaker according to still another embodiment of the present invention;

Figure 16B is a fragmentary sectional front view of Figure 16A;

Figure 17A is a fragmentary sectional front view of the circuit breaker according still another embodiment of the present invention;

Figure 17B is a perspective view of the vicinity of the arc extinguishing plate of Figure 17A;

Figure 17C is a fragmentary sectional front view of Figure 17B;

Figure 18 is a perspective view showing an arc shield in the embodiment in Figure 17a; and

Figure 19 is a perspective view showing still another embodiment of Figure 18.

In the drawings, the same symbols indicate the same or corresponding parts.

Description of the preferred embodiments

A mechanism of an arc energy consumption based on the creation of the present invention will be first described below.

Figure 2 is a view in which an arc A is produced between contactors 4 and 7. In Figure 2, character T designates a flow of thermal energy which is dissipated from the arc A through the contactors, character m flows of the energy of metallic particles which are released from an arc space, and character R flows of energy caused by a light which is irradiated from the arc space. In Figure 2, the energy injected to the arc A is generally consumed by the flows T, m and R of the above three energies. The thermal energy T which is conducted to electrodes of these energies is extremely small, and most of the energies is carried away by the flows m and T. In the mechanism of the consumption of the energy of the arc A, it is heretofore considered that the flows m in Figure 2 are almost of these energies, and the energy of the flows R is substantially ignored, but it has been clarified by the recent studies of the present inventors that the consumption of the energy of the flows R and hence the energy of light is so huge as to reach approx. 70% of the energy injected to the arc A.

In other words, the consumption of the energy injected to the arc A can be analyzed as below.

$$P_W = V \cdot I = P_K + Pth + P_R$$

$$P_K = \frac{1}{2} mV^2 + m \cdot C_p \cdot T$$

where

P_W: instantaneous injection energy

V: arc voltage

I: current

V · I: instantaneous electric energy injected to the arc

P_K: quantity of instantaneous energy consumption which is carried by the metallic particles

$mv^2/2$: quantity of instantaneous energy consumption carried away when the metallic particles of mg scatter at a speed v

$m \cdot C_p \cdot T$: quantity of instantaneous energy consumption carried away when the gas (the gas of the metallic particles) of constant-pressure specific head C_p

Pth: quantity of instantaneous energy consumption carried away from the arc space to the contactor via thermal conduction

P_R: quantity of instantaneous energy consumption irradiated directly from the arc via light.

The above quantities are varied according to the shape of the contactors and the length of the arc. When the length of the arc is 10 to 20 mm, P_K=10 to 20%, Pth=5%, and P_R=75 to 85%.

The state that the arc A is enclosed in the container is shown in Figure 3. When the arc A is enclosed in the container 3, the space in the container 3 is filled with the metallic particles and becomes the state of high temperature. The above state is strong particularly in the gas space Q (the space Q designated by hatched lines in Figure 3) in the periphery of an arc positive column A. The light irradiated from the arc A is irradiated from the arc positive column A to the wall of the container 3, and is reflected on the wall. The reflected light is scattered, is passed again through the high temperature space in which the metallic particles are filled, and is again irradiated to the wall surface. Such courses are repeated until the quantity of light becomes zero. The path of the light in the meantime is shown by Ra, Rb, Rc and Rc in Figure 3.

The consumption of the light irradiated from the arc A is following two points in the above course.

(1) Absorption of the wall surface

(2) Absorption by the arc space and peripheral (high temperature) gas space and hence by the gas space.

The light irradiated from the arc includes wavelengths from far ultraviolet ray less than 2000 Å (200 nm) to far infrared ray more than 1 μm in all wavelength range of continuous spectra and linear spectra. The wall surface of the general container merely has the light absorption capability only in the range of approx. 4000 Å to 5500 Å (400—500 nm) even if the surface is black, and partly absorbs in the other range, but almost reflects. However, the absorptions in the arc space and the peripheral high temperature gas space become as below.

When the light of wavelength λ is irradiated to the gas space having a length L, and uniform composition and temperature, the quantity of light absorption by the gas space can be calculated as below.

$$Ia{-}A \cdot n \cdot LIin \qquad (1)$$

where

Ia: absorption energy by gas

Ae: absorption probability

Iin: irradiated light energy

n: particle density

L: length of light path of the light

However, the formula (1) represents the quantity of absorption energy to special wavelength λ. The Ae is the absorption probability to the special wavelength λ, and is the function of the wavelength λ, gas temperature and type of the particles.

In the formula (1), the absorption coefficient becomes the largest value in the gas of the same state as a light source gas for irradiating the light (i.e., the type and the temperature of the particles are the same) in both the continuous spectra and the linear spectra according to the teaching of the quantum mechanics. In other words, the arc space and the peripheral gas space absorb the most light irradiated from the arc space.

In the formula (1), the quantity Ia of the absorption energy of the light is proportional to the length L of the light path. As shown in Figure 3, when the light from the arc space is reflected on the wall surface, the L in the formula (1) is increased by the times of the number of reflections of the light, and the quantity of the light energy absorbed at the high temperature section of the arc space is increased.

This means that the energy of the light irradiated by the arc A is eventually absorbed by the gas in the container 3, thereby rising the gas temperature and accordingly the gas pressure.

It is on the premise of the present invention that, in order to effectively absorb the energy of the light which reaches approx. 70% of the energy injected to the arc, a special material is used in such a manner that one or more types of fiber, net and highly porous material having more than 35% of porosity for effectively absorbing the light irradiated from the arc are selectively disposed at the special position for receiving the energy of the light of the arc in the container of the circuit breaker, thereby absorbing a great deal of the light in the container to lower the temperature of the gas space and to lower the pressure.

The above-described fiber is selected from inorganic series, metals, composite materials, woven materials and non-woven fabric, and is necessary to have thermal strength since it is installed in the space which is exposed with the high temperature arc.

The above-described net includes inorganic series, metals, composite materials, and further superposed materials in multilayers of fine metal gauze, woven strands to be selected. In the case of the net, it is also necessary to have thermal strength.

Of the above-described materials of the fiber and the net, the inorganic series adaptively include ceramics, carbon, asbestos, and the optimum metals include Fe, Cu, and may include plated Zn or Ni.

The highly porous blank generally exists in the materials of the ranges of metals, inorganic series and organic series of the materials which have a number of fine holes in a solid structure, and are classified in the relationship between the material and the fine holes into one which contains as main body solid particles sintered and solidified at the contacting points therebetween and the other which contains as main body holes in such a manner that the partition walls forming the holes are solid material. In the present invention, the blank means the material before being machined to a concrete shape, so-called "a material".

When the blanks are further finely classified, the blank can be classified into the blank in which the gaps among the particles exists as fine holes, the blank in which the gaps among the particles commonly exist in the fine holes of the holes in the particles, and the blank which contains foamable holes therein. The blanks are largely classified into the blank which has air permeability and water permeability, and the blank which has pores individually independent from each other without air permeability.

The shape of the above fine holes is very complicated, and is largely classified into open holes and closed holes, the structures of which are expressed by the volume of the fine holes or porosity, the diameter of the fine holes and the distribution of the diameters of the fine holes and specific surface area.

The true porosity is expressed by the void volume of the rate of the fine hole volume of all the open and closed holes contained in the porous blank with respect to the total volume (bulk volume) of the blank, i.e., percentage, which is measured by a substitution method and an absorption method with liquid or gas, but can be calculated as below as defined in the method of measuring the specific weight and the porosity of a refractory heat insulating brick of JISR 2614 (Japanese Industrial Standard, the Ceramic Industry No. 2614).

$$\text{True porosity} = \left(1 - \frac{\text{Bulk specific weight}}{\text{True specific weight}}\right) \times 100\%$$

The apparent porosity is expressed by the void volume of the rate of the volume of the open holes with respect to the total volume (bulk volume) of the blank, i.e., percentage, which can be calculated as below as defined by the method of measuring the apparent porosity, absorption rate and specific weight of a refractory heat insulating brick of JISR 2205 (Japanese Industrial Standard, the Ceramic Industry No. 2205).

The apparent porosity may also be defined as an effective porosity.

$$\text{Apparent porosity} = \frac{(\text{water saturated weight}) - (\text{dry weight})}{(\text{water saturated weight}) - (\text{weight in water})} \times 100\%$$

The diameter of the fine hole is obtained by the measured values of the volume of the fine holes and the specific surface area, and includes several Å (Angstrom, 1 Å=100 pm) to several mm from the size near the size of atom or ion to the boundary gap of particle group, which is generally defined as the mean value of the distribution. The diameter of the fine hole of the porous blank can be obtained by measuring the shape, size and distribution of the pore with a microscope, by a mercury press-fitting method. In order to accurately know the shape of composite pore and the state of the distribution of the pores, it is generally preferable to employ the microscope as a direct method.

The measurement of the specific surface area is performed frequency by a BET method which obtains by utilizing adsorption isothermal lines in the respective temperatures of various adsorptive gases, and nitrogen gas is frequency used.

The patterns in the absorption of the energy of the light and the decrease of the gas pressure by the absorption with the special material as the premise of the present invention will be described with an example of an inorganic porous material.

Figure 4 is a perspective view showing an inorganic porous blank, and Figure 5 is an enlarged fragmentary sectional view of Figure 4. In Figures 4 and 5, numeral 33 designates an inorganic porous blank, and numeral 34 open holes communicating with the surface of the blank. The diameters of the hole 34 are distributed in the range from several micron (μm) to several mm in various manner.

In case that the light is incident to the hole 34 when the light is incident to the blank 33 as designated by R in Figure 5, the light is irradiated to the wall surface of the blank, is then reflected on the wall surface, is reflected in multiple ways in the hole, and is eventually absorbed by 100% to the wall surface. In other words, the light incident to the hole 34 is absorbed directly to the surface of the blank, and becomes heat in the hole.

Figure 6 shows characteristic curve diagram of the variation in the pressure in the model container in which the inorganic porous material is filled when the apparent porosity of the material is varied. In Figure 6, the abscissa axis is the apparent porosity, and the ordinate axis expresses the pressure with the pressure when the porosity is 0 in the case that the inner wall of the container is formed of metal such as Cu, Fe or Al as 1 as the reference. As the experimental conditions, an AgW contacts are installed in the predetermined gap of 10 mm in a sealed container of a cube having 10 cm of one side, an arc of sinusoidal wave current of

10 kA of the peak is produced for 8 msec, and the pressure in the container produced by the energy of the arc is measured.

The inorganic porous material used in the above embodiment is porous porcelain which is prepared by forming and sintering the raw material of the porcelain of corodierite added with inflammable or foaming agent thereto to porous material, which has 10 to 300 microns of the range of mean diameter of fine hole, 20, 30, 35, 40, 45, 50, 60, 70, 80 and 85% of apparent porosity of the porous blank, using various samples of 50 mm×50 mm×4 mm (thickness) disposed in the wall surface of the container to cover 50% of the surface area of the inner surface of the container.

As the diameter of the fine holes, the mean diameter which slightly exceeds the range of the wavelength of the light to be absorbed and the rate of the fine holes occupying the surface, i.e., the degree of the specific surface area of the fine holes become a problem. In the absorption of the light in the fine holes, the deep holes cause more effective, and communicating pores are preferable. Since the light irradiated by the switch from the arc A is distributed in the range of several hundreds Å (1 Å=100 pm) to 10000 A (1 µm), the fine holes of several thousands Å to several 1000 µm of mean diameter, which slightly exceeds the above wavelengths, are adequate, and the highly porous material which exceeds 35% of the apparent porosity in the area of the holes occupying the surface is adapted for absorbing the light irradiated from the arc A. The effect can be particularly raised when the upper limit of the diameter of the fine holes is in the range less than 1000 µm and the specific surface area of the fine holes is larger. According to the experiments, it is confirmed that preferably absorbing characteristic can be obtained to the light irradiated from the arc in the material having 5 µm to 1 mm of mean diameter of the fine holes. It is also observed that the blank of glass having 5 or 20 µm preferably absorbs the light irradiated from the arc A.

As seen from the characteristic curve a in Figure 6, the pores of the inorganic porous material absorbs the light energy, and effect to lower the pressure in the circuit breaker, which increases as the apparent porosity of the porous blank is increased, which is remarkably as the porosity becomes larger than 35%, and which is confirmed in the range up to 85%. When the porosity is further increased, it is necessary to correspond by further increasing the thickness of the porous material.

When the porosity is increased in the relationship between the apparent porosity and the mechanical strength of the porous blank, the blank becomes brittle, the thermal conductivity of the blank decreases, and the blank becomes readily fusible by the high heat. When the porosity is decreased, the effect of reducing the pressure in the circuit breaker is reduced. Accordingly, the optimum apparent porosity of the porous blank in the practical use is in the range of 40 to 70% as highly porous material.

The characteristic trend of Figure 6 can also be applied to the general inorganic porous materials, and this can be assumed from the above description as to the absorption of the light.

Some prior-art circuit breaker uses the inorganic material, but its object is mainly to protect the organic material container against the arc A, and the necessary characteristics include the arc resistance, lifetime, thermal conduction, mechanical strength, insulation and carbonization remedy. The inorganic material which satisfies these necessities is composed of the material which has a trend of low porosity, and the object is different from the object of the present invention, and the apparent porosity of the prior-art material is approx. 20%.

The highly porous blanks have inorganic, metallic and organic series, and the inorganic materials are particularly characterized as the insulator and the high melting point material. These two characteristics are adapted as the material to be installed in the container of the circuit breaker. In other words, since the blank is electrically insulating, which does not affect the adverse influence to the breakage, and since the blank is high melting point, the blank is not molten nor produce gas, even if the blank is exposed with high temperature, and the blank is optimum as the pressure suppressing material.

The inorganic porous materials have porous porcelain, refractory material, glass, and cured cement, all of which can be used to decrease the gas pressure in the circuit breaker. The porous materials of the organic series have problems in the heat resistance and gas production, the porous materials of the metal series have problems in the insulation and pressure resistance, and are respectively limited in the place to be used.

In the circuit breaker in which arc runners are respectively provided at the conductors 5 and 8, an arc produced at the contacts upon opening of the contacts is transferred to the arc runners, and hence the end sides of the arc runners via magnetic force while the arc is elongated. Since this arc has huge energy, the arc raises the temperature of the gas in the container, thereby widely dissociating and ionizing the gas and accelerating the increase in the gas becoming conductive in the container. As a result, the arc is transferred to the arc runners, is elongated, and becomes higher voltage arc. Since this high voltage arc tends to maintain lower stable voltage and the gas becoming conductive at high temperature is filled in the container, the arc reversely returns to the contacts, thereby decreasing the arc voltage. This remarkably deteriorates the breaking performance of the circuit breaker.

The present invention contemplates to eliminate the above-described problems of the prior-art circuit breaker.

Embodiments of the present invention will now be described with reference to the accompanying drawings.

Figure 7A is a perspective view for explaining the essential portion of an embodiment of the circuit

breaker according to the present invention, Figure 7B is a side sectional view of Figure 7A, and Figure 7C is a side sectional view showing the entire circuit breaker. In Figures 7A to 7C, numeral 5 designates a stationary conductor, numeral 6 a stationary contact, numeral 8 a movable conductor, numeral 9 a movable contact, numeral 32 an arc, numerals 35 and 35 side walls forming an arc light absorber, which is formed of inorganic porous material or organic and inorganic composite material having more than 35% of apparent porosity of a blank, and which are arranged to confront each other at both side surfaces of the arc 32 produced between the contacts 6 and 9 except the side surface portions confronting the moving locuses of the conductor 8 and the contact 9.

The other portions are similar to the prior-art circuit breaker, and will be omitted. The operation of the circuit breaker of the invention will be described. The fact that the arc is produced between the contacts 6 and 9 is similar to the prior-art, but since the side walls 35 and 35 are installed except at the arc 32 producing point, the following advantages are raised. Since the side walls 35 and 35 operate to absorb the energy of the light and to decrease the pressure as described above, the pressure of the space of the portion in which the side walls 35 and 35 exist from the arc producing point is very decreased, the force for attracting the arc 32 toward the direction of the side walls 35 and 35 (arrow directed downwards) is generated the arc 32 is thus elongated deeply to the side walls 35 and 35, the arc voltage is raised, and a current limiting operation is presented.

Since the pressure suppression in the cover 1 and the base 2 can be effectively performed, the following effects can be raised, thereby inexpensively providing a high performance and reliability circuit breaker with safety. (1) Since the damage of a molded case at the breaking time which tends to occur in the prior-art circuit breaker is prevented, the quantity of molding blank forming the cover 1 and the base 2 can be largely saved. When the quantity of the blank is not saved, more inexpensive gravy blank having low mechanical strength can be selected.

(2) Since the increase in the internal pressure at the breaking time can be suppressed, the quantity of arc discharging spark can be reduced, a secondary fire accident due to shortcircuit of a power supply in and out the molded case which tends to occur at the time of breaking particularly large current can be preventively eliminated.

(3) Since the temperature rise of the arc can be suppressed by the suppression of the internal pressure rise and the arc 32 is interposed between the side walls 35 and 35 from both sides, the decreases in the megohm between the metal in the vicinity of the arc 32 and the load of the power supply caused by the melting and evaporating of the insulator and the megohm between the phases can be prevented.

(4) Since no light absorber is arranged on the side surfaces confronting the moving locuses of the contact 9 and the conductor 8, the contact 9 and the conductor 8 are not contacted with the side walls 35 and 35 due to the lateral fluctuation occurs during the operation of the conductor 8, thereby eliminating the precipitation of powder from the side walls 35 and 35 and the apprehension of cracks of the side walls 35 and 35. The megohm between the contacts 6 and 9 after the breakage can be improved.

(5) Since the surfaces of the side walls 35 and 35 are not vitrified but crystallized due to the direct irradiation of the arc 32 when the inorganic porous material which mainly contains magnesia or zirconia is used as the porous material forming the side walls 35 and 35, the megohm of the surface is not lowered during the arc period. Accordingly, preferably breaking performance can be obtained.

(6) When the surface of the porous material forming the side walls 35 and 35 is heat treated and organic material is suitably mixed with the inorganic porous material, the precipitation of fine powder from the side walls 35 and 35 due to the vibration and impact of the circuit breaker can be prevented.

The relationship between the arc extinguishing plate relative to the present invention and the arc will be described.

The arc extinguishing plate generally has an operation which cools the arc by the magnetic force at the breaking time by attracting and driving the arc to contact the arc with the arc extinguishing plate. Thus, the arc is attracted to the arc extinguishing plate, is moved to the vicinity of the plate, and is stayed in the space. In this case, the position of the arc to be attracted to the arc extinguishing plate and to be stayed is largely varied according to the shape of the plate and the current value of the arc. The reason of the variation in the position of the arc is from the result of the magnetic force, and relates to the difference in the behavior of the arc as shown in Figures 8A and 8B.

In other words, one behavior of the arc is the case that, as shown in Figure 8, the magnetic field MF affecting the arc A is spatially locally operated as compared with the geometrical dimension of the arc extinguishing plate 14, and the arc A is attracted by the magnetism only from the front end side 14a of the plate 14, and the other behavior of the arc is the case that, as shown in Figure 8B, the arc A is sufficiently large, and the arc A is invaded to the side of the rear end 14b through the notch 14a of the plate upon receiving of the force in the direction of an arrow F by the magnetic operation with the entire plate 14. The above phenomena depend upon the two factors, i.e., the size of the arc extinguishing plate and the magnitude of the arc current.

The state that the arc A is attracted to the front end 14a of the plate 14 will be described with reference to Figures 9A and 9B.

It is generally understood that the temperature of the center of the positive column in the arc is higher than 20000°C, the temperature of the periphery of the arc is approx. 8000°C and the quantity of the light energy is remarkably large from the center. The arc A is attracted to the front end 14a of the plate 14, but the

center of existing arc A is disposed at the position slightly isolated from the plate 14. When the outer periphery Ap of the arc A is contacted with the plate 14, the arc is cooled by the contacted plate 14, and the center Ax of the positive column cannot approach to the plate 14 more than that. Accordingly, the center Ax of the positive column is stayed at the position slightly isolated from the plate 14. This is clarified directly or indirectly by the photographing means by a high speed camera or the observation of the damage on the wall surface of the container after the breakage.

Figures 10A and 10B show an arc extinguishing plate and the portion in the vicinity of the plate in the circuit breaker according to another embodiment of the present invention. In Figures 10A and 10B, side walls 35 and 35 are provided at the front positions of both the sides and of an arc extinguishing plate 14, and more particularly between the plate 14 and the contacts 6, 9, and the walls 35 and 35 are formed of inorganic porous material having more than 35% of apparent porosity as described above. The side walls 35 and 35 are fixed with refractory adhesive.

In the structure thus constructed, the plate 14 is contacted with the outer periphery Ax of the arc A as described above, and when the center Ax of the arc positive column is stayed before the plate 14, the energy R irradiated in large quantity from the center Ax can be effectively absorbed by the side walls 35 and 35.

Figure 11A to 11D show another example of the side walls 35 and 35 which are formed of the above inorganic porous material. As shown in Figure 11A, the arc A is generally attracted to the arc extinguishing plate 14, and is cooled in contact with the plate 14. At this time, since the light energy R from the arc A is irradiated as shown in Figure 11B, the side plates 35 and 35 which are disposed at the nearest position from the arc A located on the plate 14 are formed of an arc light absorber, i.e., inorganic porous material, thereby effectively absorbing the light energy R. Figure 11C is a perspective view of Figure 11A, and Figure 11C is a side view of an electric contactor for explaining the movement of the arc. In Figure 11D, when the electric contactors 4 and 7 are opened, an arc A is produced between the contacts 6 and 9, and when the distance between the contacts 6 and 9 is lengthened and the attracting operation of the plate 14 becomes effective, the arc A is driven toward the plate 14 and is contacted with the plate 14. Generally, the larger the breaking current is, the larger the distance between the contacts 6 and 9 becomes early, and the larger the attracting force of the plate 14 becomes. Accordingly, the larger the current is, the rapidly the arc A is isolated from the contacts 6 and 9, is contacted with the plate 14, and is stayed in the plate 14. The rate of occupying the staying time of the arc A during the arc producing period is sufficiently large. Consequently, when the place where is the nearest from the plate 14 and hence the side walls 35 and 35 are formed of the inorganic porous material, the light energy R from the arc A can be absorbed in large quantity by the side plates 35 and 35, thereby effectively suppressing the internal pressure in the circuit breaker.

In order that the side walls 35 and 35 provided at the side of the arc extinguishing plate 14 are provided at the optimum positions for absorbing the light energy as described above, the disposing position of the side walls 35 and 35 is selected correspondingly to the internal structure of the circuit breaker. Figures 12A and 12B show still another example in which side plates 15 and 15, and side walls 35 and 35 are respectively contacted with each other at the rear end of an arc extinguishing plate 24, and Figures 13A and 13B show still another example in which side plates 15 and 15, and side walls 35 and 35 are contacted with each other at the front end of an arc extinguishing plate 14.

Figures 14A and 14B show still another example in which the side walls 35 and 35 are provided at a notch of an extinguishing plate 14, and Figure 14 shows still another example in which the above side walls 35 and 35 are provided cooperatively with the front end and the notch of an arc extinguishing plate 14. In these cases, the arc light energy can be effectively absorbed. Further, Figures 16A and 16B show still another examples in which side walls 35 and 35 are engaged with notches 14C and 14C formed at the side of an arc extinguishing plate 14. In this case, the arc A produced between the contacts 6 and 9 and attracted by the arc extinguishing plate 14 is falled at the foot on the plate 14, is divided by the plate 14, and is moved toward the direction aparting from the contacts 6 and 9. At this time, a relatively small current can pass the space X interposed between the side walls 35 and 35 which are formed of the above inorganic porous material. On the other hand, when a large current pass the space X, the space X becomes narrow as the current moves toward the space X. Accordingly, the pressure in the space increases, with the result that the current can hardly pass the space X. The light energy is effectively absorbed by the side walls 35 and 35 which are formed of the above inorganic porous material, and the high temperature gas passing through the space X is cooled to low temperature. Consequently, the temperature of the gas in the space Y at the rear of the plate 14 becomes relatively low as compared with the other position of the circuit breaker. In other words, since the light energy is absorbed by the side walls 35 and 35 and the electric conductivity is lowered, no arc A is produced at the rear end 14b of the plate 14 as the conventional circuit breaker.

Since the energy in the circuit breaker does not rise the gas temperature but is absorbed directly in the form of the light by the side walls 35 and 35, the internal pressure of the circuit breaker is suppressed, thereby remarkably reducing the discharging spark.

Figure 17A, 17B and 17C show still another embodiment in which an arc shield surrounding around the contact provided at the conductor of an electric contactor as shown in Figure 18. The above embodiment is applied to the example shown in Figures 12A and 12B, but may be applied to other examples. More particularly, in Figures 17A, 17B, 17C and 18, numerals 101 and 102 designate arc shields which are formed of an organic insulating material such as known synthetic resin and are respectively formed at a stationary

conductor 5 and a movable conductor 8 to surround the outer peripheries of a stationary contact 6 and a movable contact 9. The shields 101 and 102 are readily formed by a method of coating the conductors 5 and 8 by painting or a method of fixing plates formed of the above synthetic resin to the conductors 5 and 8. In this case, according to the above coating means, the shields 101 and 102 are not only simply formed, but are formed inexpensively, and since the increase in the weight can be reduced at the side of the contactor 7, the inertial moments of the shields can be reduced, thereby increasing the isolating speed of the contactor 7 and accordingly enhancing the arc voltage.

Side walls 35 and 35 which are formed of a light absorber are provided as shown in Figure 17B at both sides of the front side of the arc moving direction (the direction of an arrow a in Figure 17C) from the locuses of the contacts 6 and 9. The side walls 35 and 35 are formed of a composite material which has one or more of the above-described special materials such as, fiber, net and porous material having more than 35% of apparent porosity.

The operation of the above embodiment will be described.

The arc 32 is produced between the contacts 6 and 9 in the same manner as the prior-arc circuit breaker, but since the arc shields 101 and 102 are provided at the outer peripheries of the contacts 6 and 9, the arc 32 is throttled to the narrow space. Consequently, the sectional area of the arc 32 is extremely reduced as compared with the prior-art circuit breaker which does not have the shields 101 and 102, and the arc voltage is accordingly largely raised, thereby improving the current limiting performance. Another feature of this embodiment is that the arc shields 101 and 102 are formed of organic insulator and the arc shields 103 and 104 which are formed of the above special material such as a porous material having more than 35% of porosity are installed at the position isolated toward the arc moving direction from the contacts 6 and 9. In other words, the heat resistance of the organic insulating material is not so high, but is consumed in large quantity by the heat of the arc 32, thereby discharging large quantity of evaporating particles therearound. Therefore, as shown in Figure 17C, the gas pressure is largely increased in the space X in the vicinity of the arc 32. On the other hand, since the side walls 35 and 35 are provided at the position isolated from the contacts 6 and 9, the light of the arc 32 is absorbed by the above side walls 35 and 35, and the gas pressure in the space Y can hardly increase. Consequently, the pressure difference between the spaces X and Y becomes very large, thereby producing a gas flow. In other words, the arc 32 is rapidly flowed toward the direction of an arrow a due to the above pressure difference, thereby elongating the arc length. Therefore, the arc 32 is further readily contacted with the arc extinguishing plate 14, and the arc voltage is further raised, thereby remarkably improving the current limiting performance and the breaking performance of the circuit breaker.

Figure 19 shows modified example of the stationary electric contactor 4 providing an arc shield 101. An arc moving path 104 which is formed of a groove formed toward a direction for isolating the contact 6 from the end 6a of a stationary contact 6 such as toward the arc moving direction, i.e., toward the arc extinguishing plate 14 is formed at the arc shield 101.

In this manner, the foot of the arc 32 moves on the arc moving path 104, and the arc 32 can further readily move toward the plate 14. Thus, the arc 32 is readily contacted with the plate 14, thereby improving the breaking performance of the small current range.

When the side walls 35 and 35 employ an inorganic porous material which mainly contains magnesia or zirconia, the side walls 35 and 35 are not vitrified but is crystallined. Accordingly, the insulating resistance of the surfaces of the side walls 35 and 35 are not lowered during the arc generating period, thereby obtaining preferably breaking performance. When the surfaces of the side walls 35 and 35 are heat treated and an organic material is suitably mixed with the inorganic porous material, the precipitation of powder from the side walls 35 and 35 due to the vibration and impact of the circuit breaker can be effectively prevented without disturbing the operation of lowering the internal pressure in the circuit breaker.

Claims

1. A circuit breaker with an arc light absorber comprising a pair of electric contactors (4, 6; 7, 9) contained in an insulating container (3) for opening or closing an electric circuit, the contactors comprising electric conductors (5, 8) provided with contacts (6, 9); as well as an arc extinguishing plate (14) for extinguishing an arc produced between said contacts (6, 9) when said electric contactors (4, 7) are opened, characterized in that at the position of the arc extinguishing plate (14) and outside of the area that the contacts (6, 9) traverse when they are opened and closed there is provided a pair of mutually confronting side walls (35), so that the arc being produced between said contacts (6, 9) is discharged in the space between said pair of confronting side walls (35), said side walls (35) being formed of a composite material out of fiber, net or porous material having more than 35% of apparent porosity.

2. A circuit breaker with an arc light absorber according to Claim 1, characterized in that said side walls (35) are provided at the front end side of said arc extinguishing plate (14).

3. A circuit breaker with an arc light absorber according to Claim 1, characterized in both side end supports of said arc extinguishing plate (14) are formed of said side walls (35).

4. A circuit breaker with an arc light absorber according to Claim 1, characterized in that said side walls (35) are provided from the position corresponding to the rear end (14b) of opposite side in said arc

extinguishing plate (14) to the side confronting said contacts (6, 9) to the rear position of said arc extinguishing plate (14).

5. A circuit breaker with an arc light absorber according to Claim 1, characterized in that said side walls (35) are extended from the position corresponding to both sides of the front end of said arc extinguishing plate (14) to the front position of said arc extinguishing plate (14).

6. A circuit breaker with an arc light absorber according to Claim 1, characterized in that notches (14c) are formed at both side edges of said arc extinguishing plate (14), and said side walls (35) are respectively engaged with the notches (14c) of said arc extinguishing plate (14).

7. A circuit breaker with an arc light absorber according to Claim 1, characterized in that arc shields (101, 102) which are arranged to surround said contacts (6, 9) and which are formed of a high resistance material having a resistivity higher than said electric conductors (5, 8) and are fixed to said electric conductors.

8. A circuit breaker with an arc light absorber according to Claim 1, characterized in that arc shields (101, 102) which are arranged to surround said contacts (6, 9) and which are formed of a high resistance material having a resistivity higher than said electric conductors (5, 8) are fixed to said electric conductors (5, 8) and arc moving paths for moving the arc are formed at said arc shields.

9. A circuit breaker with an arc light absorber according to Claim 1, characterized in that the surfaces of said side walls (35) are hardened by a heat treatment.

10. A circuit breaker with a an arc light absorber according to Claim 1, characterized in that a porous material forming said side walls (35) comprises in composition magnesia or zirconia.

11. A circuit breaker with an arc light absorber according to Claim 1, characterized in that said side walls (35) are formed of an inorganic porous material, which is a porous blank comprising 40% to 70% of apparent porosity.

12. A circuit breaker with an arc light absorber according to Claim 7, characterized in that said inorganic porous material is selected from the group consisting of porous porcelain, refractory material, glass and cured cement.

13. A circuit breaker with an arc light absorber according to Claim 7, characterized in that said inorganic porous material comprises several thousands Å (1 Å=100 pm) to several 1000 µm of mean diameter of fine holes.

Patentansprüche

1. Stromunterbrecher mit einem Lichtbogenabsorber, bestehend aus einem Paar von innerhalb einer Isolierkammer (3) angeordneten Schaltarmen (4, 6; 7, 9) zum Öffnen oder Schließen eines elektrischen Stromkreises, wobei die Schaltarme aus elektrischen Leitern (5, 8) bestehen, an welchen Kontakte (6, 9) vorgesehen sind, und wobei eine Lichtbogenlöschplatte (14) vorgesehen ist, mit welcher der zwischen den Kontakten (6, 9) sich ergebende Lichtbogen gelöscht wird, sobald eine Öffnung der Schaltarme (4, 7) vorgenommen wird, dadurch gekennzeichnet, daß an der Position der Lichtbogenlöschplatte (14) und außerhalb des beim Öffnen und Schließen der Kontakte (6, 9) durchquerten Bereiches ein Paar von gegenüberliegenden Seitenwandungen (35) vorgesehen ist, so daß der zwischen den Kontakten (6, 9) gebildete Lichtbogen in den Raum zwischen diesen beiden gegenüberliegenden Seitenwandungen (35) geführt ist, wobei die Seitenwandungen (35) aus einem zusammengesetzten Material aus Fasern, Netz oder einem porösen Material hergestellt sind, welches mehr als 35% vorhandene Porosität besizt.

2. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 1, dadurch gekennzeichnet, daß die Seitenwandungen (35) an der vorderen Endseite der Lichtbogenlöschplatte (14) vorgesehen sind.

3. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 1, dadurch gekennzeichnet, daß an beiden Seitenenden der Lichtbogenlöschplatte (14) Halteelemente der Seitenwandungen (35) vorgesehen sind.

4. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 1, dadurch gekennzeichnet, daß die Seitenwandungen (35) sich von einer Position, welche dem rückwärtigen Ende (14b) der gegenüberliegenden Seite der Lichtbogenlöschplatte (14) auf der Seite der Kontakte (6, 9) bis zur rückwärtigen Position der Lichtbogenlöschplatte (14) erstrecken.

5. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 1, dadurch gekennzeichnet, daß die Seitenwandungen (35) sich von der Position entsprechend den beiden Seiten des vorderen Endes der Lichtbogenlöschplatte (14) bis zur vorderen Position der Lichtbogenlöschplatte (14) erstrecken.

6. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 1, dadurch gekennzeichnet, daß auf beiden Seitenkanten der Lichtbogenlöschplatte (14) Aussparungen (14c) vorgesehen sind, und daß die Seitenwandungen (35) mit den entsprechenden Aussparungen (14c) der Lichtbogenlöschplatte (14) in Eingriff gelangen.

7. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 1, dadurch gekennzeichnet, daß zusätzlich die Kontakte (6, 9) umgebende Lichtbogenschilde (101, 102) vorgesehen sind, welche aus einem hochohmigen Material hergestellt sind, dessen Widerstandswert höher als der der elektrischen Leiter (5, 8) ist, wobei diese Lichtbogenschilde an den elektrischen Leitern befestigt sind.

8. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 1, dadurch gekennzeichnet, daß die die Kontakte (6, 9) umgebenden Lichtbogenschilde (101, 102) aus einem hochohmischen

Widerstandsmaterial mit einem Widerstandswert größer als der der elektrischen Leiter (5, 8) an den elektrischen Leitern (5, 8) befestigt sind, und daß der von dem Lichtbogen durchlaufene Weg durch die Lichtbogenschilde festgelegt ist.

9. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 1, dadurch gekennzeichnet, daß die Oberflächen der Seitenwandungen (35) mit Hilfe einer Wärmebehandlung gehärtet sind.

10. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 1, dadurch gekennzeichnet, daß das die Seitenwandungen (35) bildende poröse Material aus einer Zusammensetzung aus Magnesiumoxid (Magnesia) oder Zirkoniumoxid (Zirkonia) besteht.

11. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 1, dadurch gekennzeichnet, daß die Seitenwandungen (35) aus einem inorganischen porösen Material bestehen, dessn anscheinende Porosität zwischen den Werten von 40 und 70% liegt.

12. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 7, dadurch gekennzeichnet, daß das inorganische poröse Material aus der Gruppe von porösem Porzellan, einem refraktorischen Material, Glas oder gehärtetem Zement besteht.

13. Stromunterbrecher mit einem Lichtbogenabsorber nach Anspruch 7, dadurch gekennzeichnet, daß das inorgànischen poröse Material feine Kanäle aufweist, deren mittlerer Durchmesser im Bereich zwischen mehreren 1000 Å (1 Å=100 pm) bis mehrere 1000 µ besteht.

Revendications

1. Disjoncteur avec un absorbeur d'arc comprenant une paire de contacteurs électriques (4, 6; 7, 9) contenus dans un conteneur isolant (3) pour ouvrir ou fermer un circuit électrique, les contacteurs comprenant des conducteurs électriques (5, 8) pourvus de contacts (6, 9); ainsi qu'une plaque (14) d'extinction de l'arc pour éteindre un arc produit entre lesdits contacts (6, 9) lorsque lesdits contacteurs électriques (4, 7) sont ouverts, caractérisé en ce qu'à la position de la plaque (14) d'extinction de l'arc et en dehors de la zone que traversent les contacts (6, 9) lorsqu'ils sont ouverts et fermés, deux parois latérales mutuellement face à face (35) sont prévues, de manière que l'arc produit entre les contacts (6, 9) soit déchargé dans l'espace entre lesdites parois latérales face à face (35), lesdites parois latérales (35) étant formées d'un matériau composite pris parmi des fibres, un filet ou une matière poreuse ayant plus de 35% de porosité apparente.

2. Disjoncteur avec un absorbeur d'arc selon la revendication 1, caractérisé en ce que lesdites parois latérales (35) sont prévues du côté extrémité avant de ladite plaque (14) d'extinction de l'arc.

3. Disjoncteur avec un absorbeur d'arc selon la revendication 1, caractérisé en ce que les deux supports extrêmes latéraux de ladite plaque d'extinction de l'arc (14) sont formés desdites parois latérales (35).

4. Disjoncteur avec un absorbeur d'arc selon la revendication 1, caractérisé en ce que lesdites parois latérales (35) sont prévues de la position correspondant à l'extrémité arrière (14b) du côté opposé dans ladite plaque (14) d'extinction de l'arc au côté se trouvant face auxdits contacts (6, 9) à la position arrière de ladite plaque (14) d'extinction de l'arc.

5. Disjoncteur avec un absorbeur d'arc selon la revendication 1, caractérisé en ce que lesdites parois latérales (35) sont étendues de la position correspondant aux deux côtés de l'extrémité avant de ladite plaque (14) d'extinction de l'arc jusqu'à la position avant de ladite plaque (14) d'extinction de l'arc.

6. Disjoncteur avec un absorbeur d'arc selon la revendication 1, caractérisé en ce que des encoches (14c) sont formées sur les deux bords latéraux de ladite plaque (14) d'extinction de l'arc et lesdites parois latérales (35) sont respectivement en engagement avec les encoches (14c) de ladite plaque (14) d'extinction de l'arc.

7. Disjoncteur avec un absorbeur d'arc selon la revendication 1, caractérisé en ce que des blindages (101, 102) de l'arc qui sont agencés pour entourer lesdits contacts (6, 9) et qui sont formés d'un matériau de haute résistance ayant une résistivité supérieure auxdits conducteurs (5, 8) sont fixés auxdits conducteurs électriques.

8. Disjoncteur avec un absorbeur d'arc selon la revendication 1, caractérisé en ce que lesdits blindages de l'arc (101, 102) qui sont agencés pour entourer lesdits contacts (6, 9) et qui sont formés d'un matériau de haute résistance ayant une résistivité supérieure auxdits conducteurs électriques (5, 8) sont fixés auxdits conducteurs électriques (5, 8) et des trajets de déplacement de l'arc pour déplacer l'arc sont formés sur lesdits blindages d'arc.

9. Disjoncteur avec un absorbeur d'arc selon la revendication 1, caractérisé en ce que les surfaces desdites parois latérales (35) sont durcies par un traitement thermique.

10. Disjoncteur avec un absorbeur d'arc selon la revendication 1, caractérisé en ce qu'une matière poreuse formant lesdites parois latérales (35) comprend, dans sa composition, de la magnésie ou de l'oxyde de zirconium.

11. Disjoncteur avec un absorbeur d'arc selon la revendication 1, caractérisé en ce que lesdites parois latérales (35) sont formées d'une matière poreuse inorganique qui est une ébauche poreuse comprenant 40% à 70% de porosité apparente.

12. Disjoncteur avec un absorbeur d'arc selon la revendication 7, caractérisé en ce que ladite matière poreuse inorganique est choisie dans le groupe consistant en porcelaine poreuse, matière réfractaire, verre et ciment durci.

13. Disjoncteur avec un absorbeur d'arc selon la revendication 7, caractérisé en ce que ladite matière poreuse inorganique comprend plusieurs milliers d'Angströms (1 Å=100 pm) à plusieurs 1.000 μm du diamètre moyen de trous fins.

FIG. 1(A)

PRIOR ART

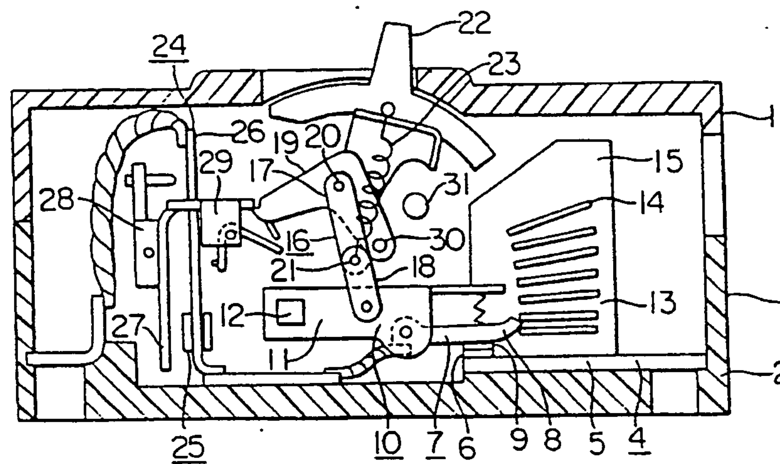


FIG. 1(B)

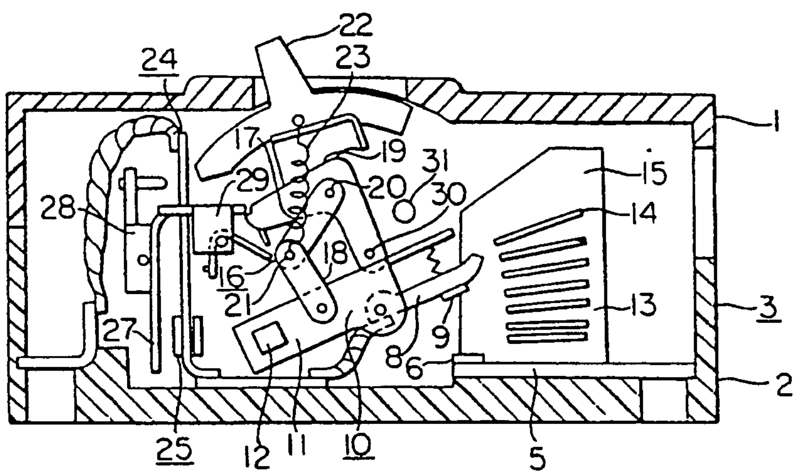
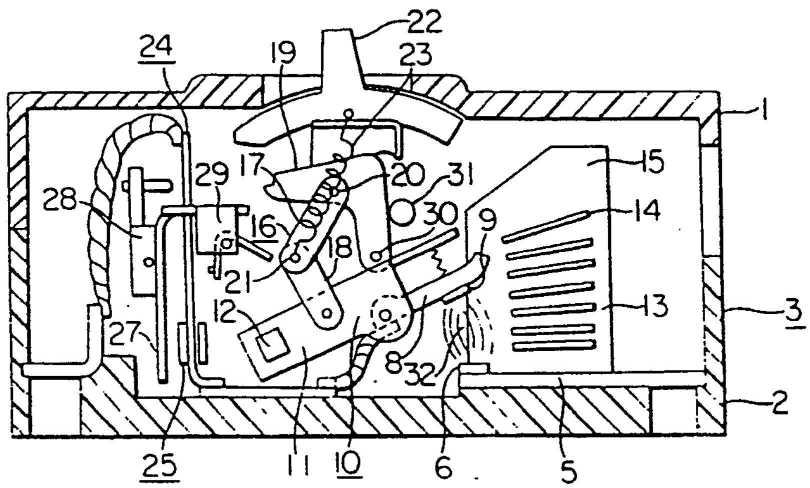


FIG. 1(C)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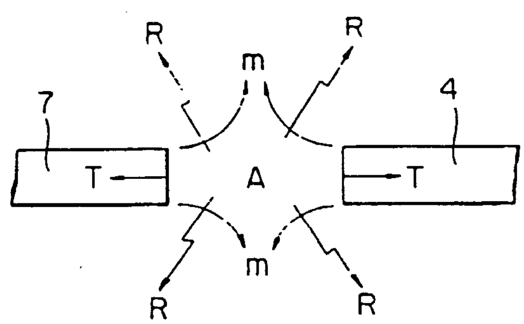
8
32
2
25
11
10
6
5

FIG. 2


R
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m
7
4
T
A
T
m
R
R

FIG. 3

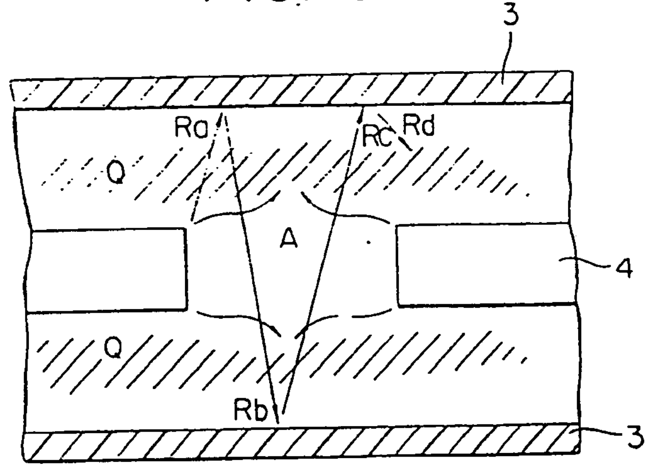

FIG. 4

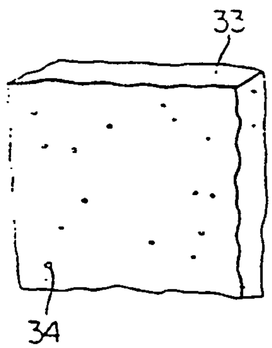

FIG. 5

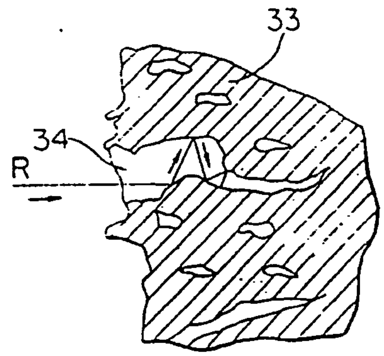

FIG. 6

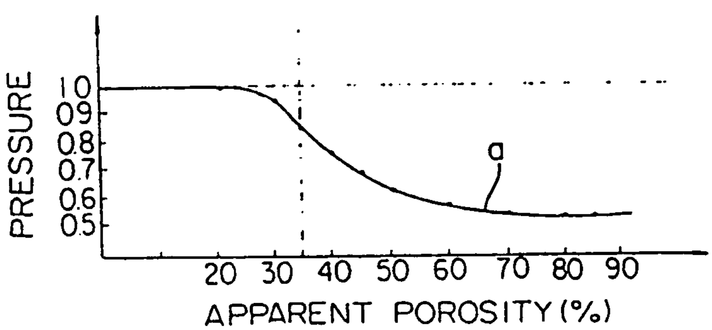

FIG. 7(A)

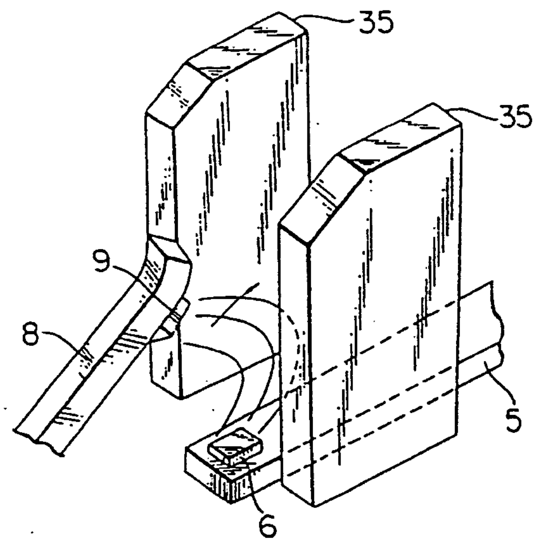

FIG. 7(B)

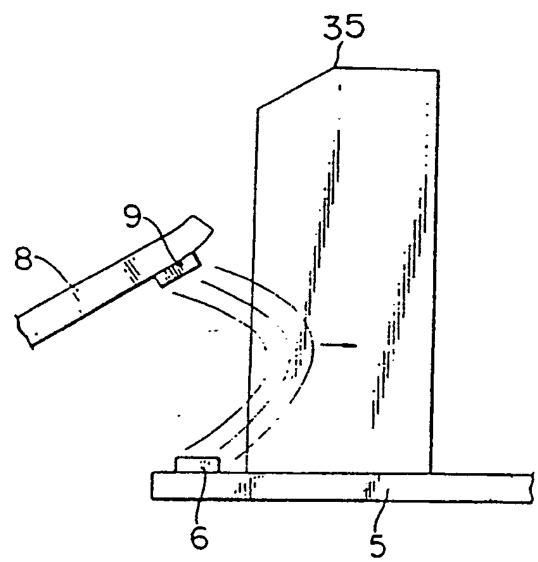

FIG. 7(C)

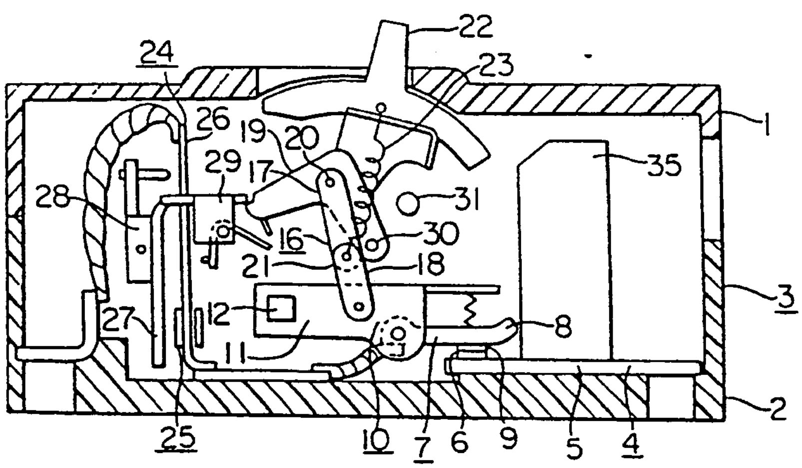

FIG. 8(A)

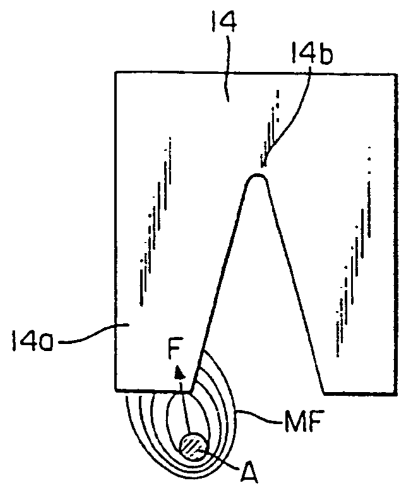

FIG. 8(B)

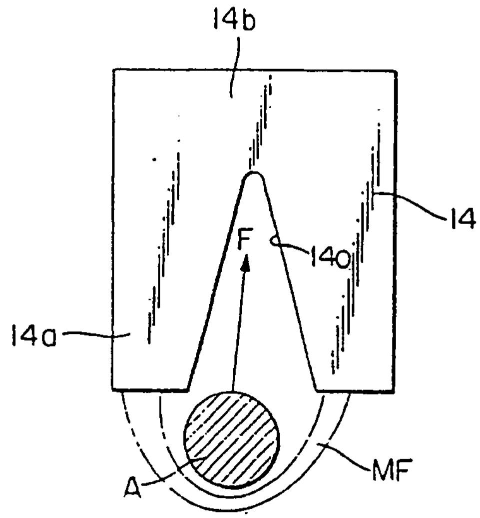

FIG. 9(A)

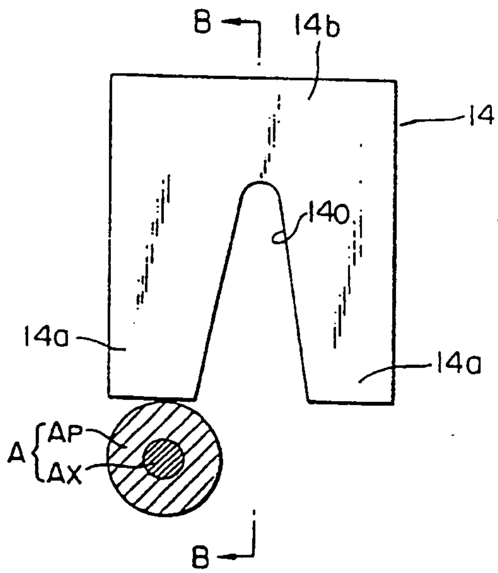

FIG. 9(B)

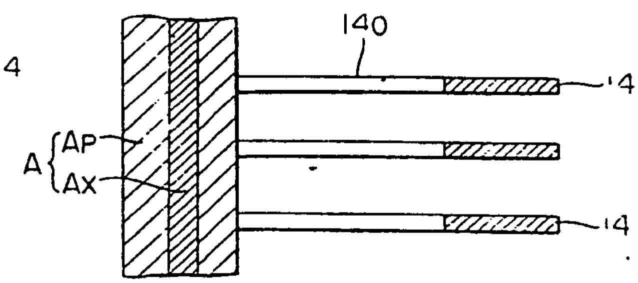

FIG. 10(A)

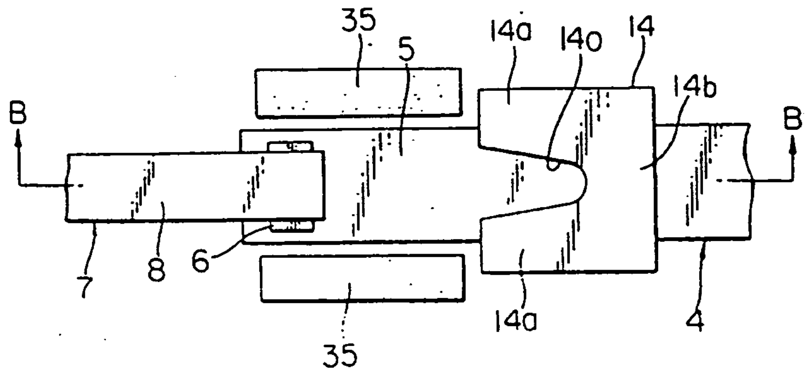

FIG. 10(B)

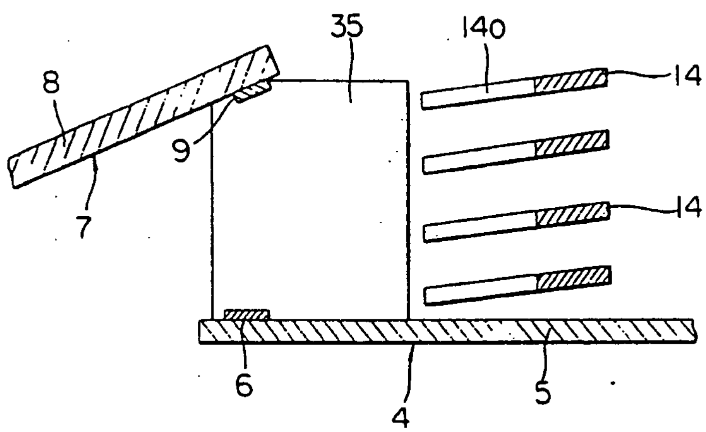

FIG. 11(A)

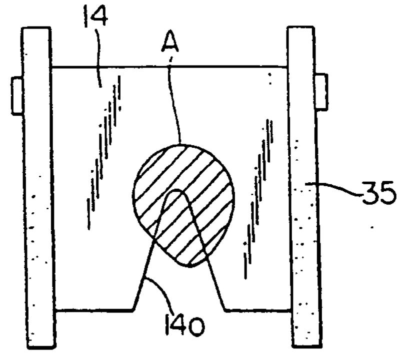

FIG. 11(B)

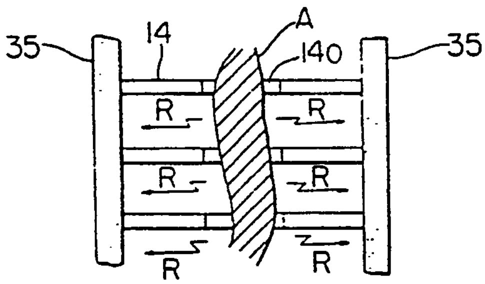

FIG. 11(C)

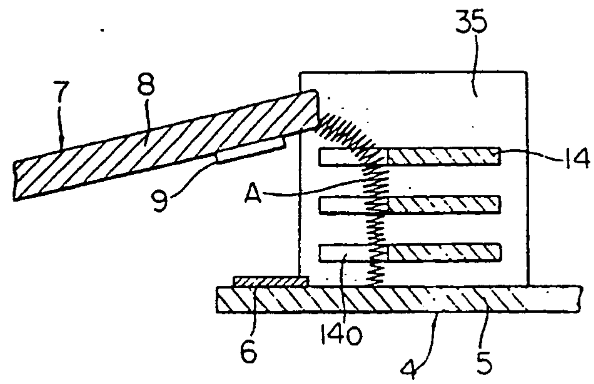

FIG. 11(D)

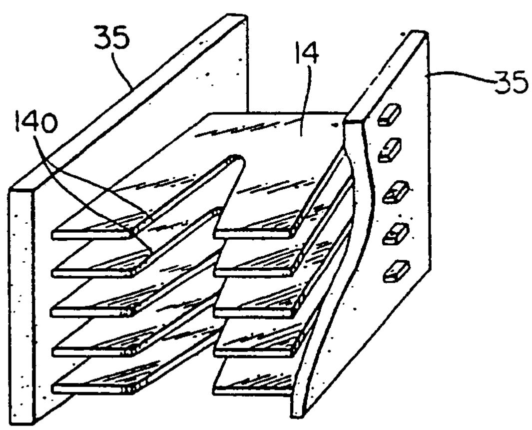

FIG. 12(A)

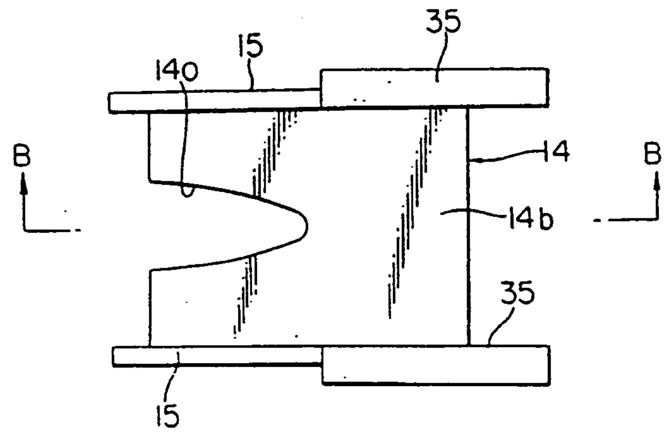

FIG. 12(B)

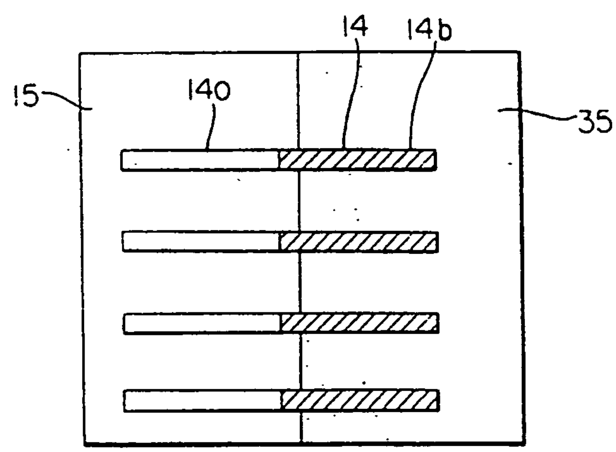

FIG. 13(A)

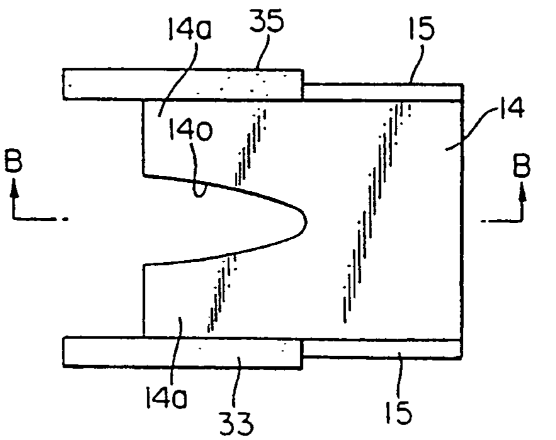

FIG. 14(A)

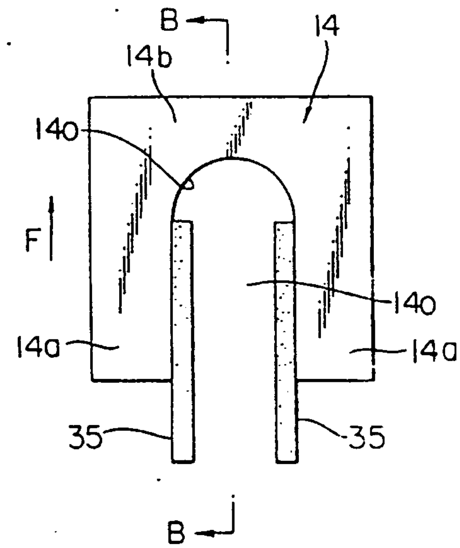

FIG. 13(B)

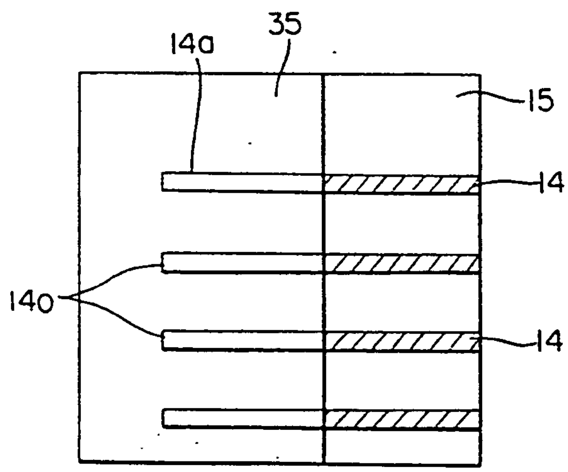

FIG. 14(B)

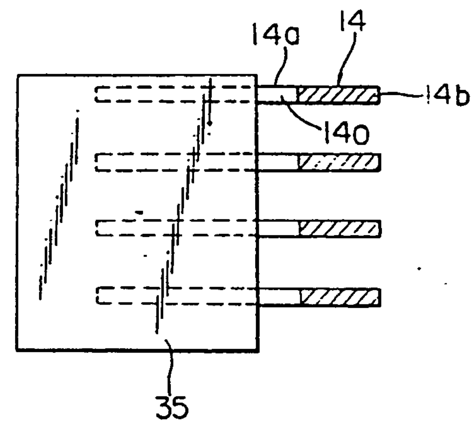

FIG. 15

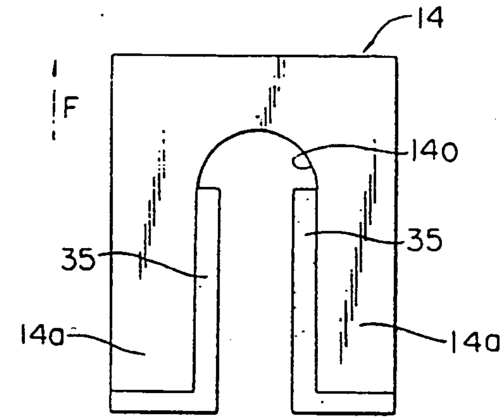

FIG. 16(A)

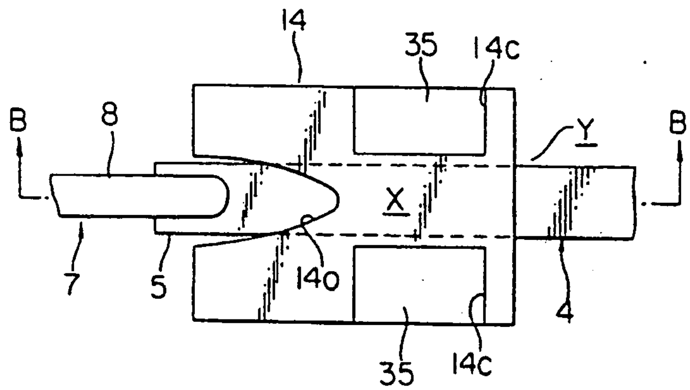

FIG. 16(B)

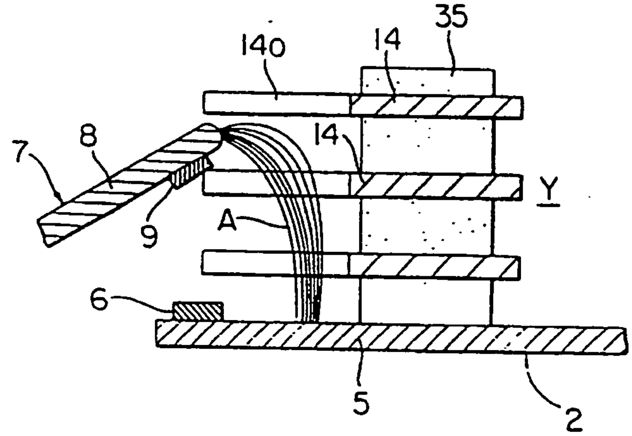

FIG. 17(A)

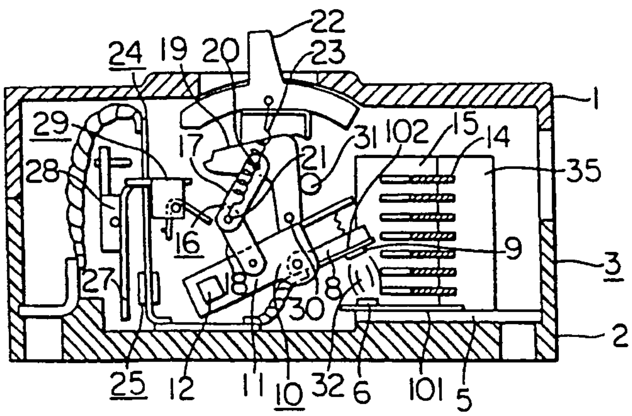

FIG. 17(B)

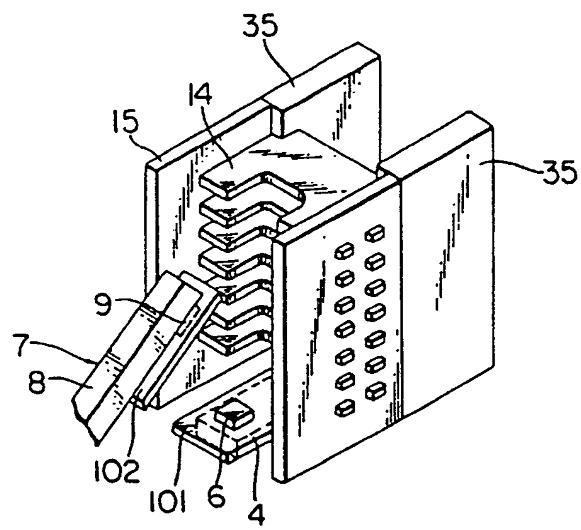

FIG. 17(C)

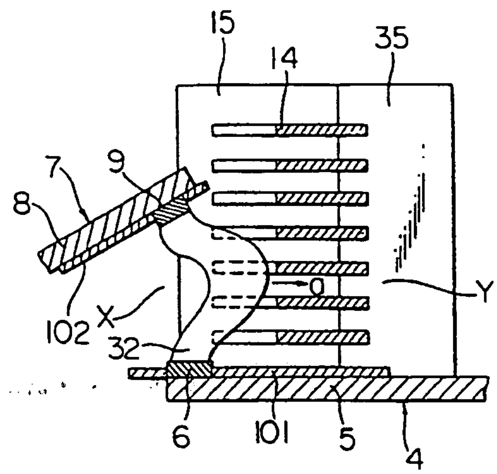

FIG. 18

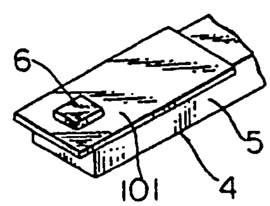

FIG. 19